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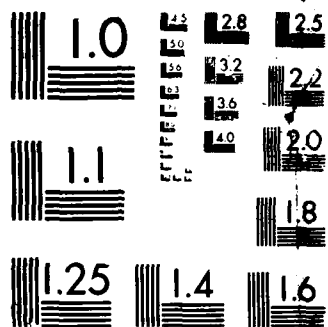
CONSTRUCTION PLANT SUPPORT FOR LOC (LINE OF COMMUNICATIONS) DEVELOPMENT(U) ARMY WAR COLL CARLISLE BARRACKS PA S H YOUNG 31 MAR 88

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the crushing capability has been moved to engineer units in the Reserve and National Guard. The lack of use of crushing plants in training and limited use in the Reserve and Guard have allowed the equipment to become old and unserviceable due to a shrinking source of repair parts. In face, some parts are just not available. The importance of crushing equipment has been shown historically in WWll and Vietnam and presently in the engineer deployments to Latin America. History has further shown a need to increase the capacity of standard equipment now in engineer units. The present equipment has deteriorated and must be replaced with a larger capacity if engineers are going to be able to accomplish the mission of LOC construction and maintenance. Without LOCs the combat commanders will not be able to stockpile, to move supplies, or to maneuver forces effectively.

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CONSTRUCTION PLANT SUPPORT FOR LOC DEVELOPMENT

An Individual Study Project  
Intended for Publication

by

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U.S. Army War College  
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# ABSTRACT

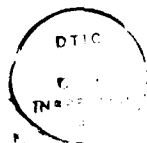
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## INTRODUCTION

The Corps of Engineers' limited ability to provide line of communications (LOC) construction support to the Army and other Services must be addressed. LOC construction generally involves the building or maintenance of roads, railroads, airfields, and port facilities. This construction is a major priority for heavy engineer units to insure that combat forces and their supplies can be moved forward to engage the enemy. Napoleon's maxim that "An Army travels on its stomach," still applies, except that modern armies carry much more in the way of supplies and travel in wheeled and tracked vehicles supported by helicopters, airplanes, and ships. The tremendous increases in supplies have made modern LOCs much more important to the combat commander today because he cannot take everything with him into battle. Instead, he must rely on his source of resupply or his logistics tail.

Responsibility for LOC construction within the Army lies with the Corps of Engineers. In addition, the Corps provides construction support for all Services as requirements demand. On the modern battlefield, it is reasonable to expect that construction or repair of LOC facilities will become critical to deploy and support combat forces.

LOC construction requires substantial amounts of construction equipment ranging from trucks, dozers, and compaction equipment to specialized engineer equipment such as mobile rock crusher plants. The status of the U.S. Army's rock crusher or construction plants needs to be examined. Rock crushers produce aggregate which is crushed rock. Because aggregate is the major construction material in road, railroad, airport, and general construction, a source must be obtained to support most construction projects. Rock crushers produce this critical material from natural rock formations, gravel pits, or stream beds by crushing large feeder rock into sizes necessary for construction. For years, the Army has had and used this special purpose equipment. It was used in support of operations in WWII in Europe to move and resupply ground forces. In the South Pacific, it was used to support airfield construction which supported the island hopping campaigns of General MacArthur. Vietnam provided another opportunity for a major road construction program that connected the many regions of the country.

The basic problem today has evolved from a lack of emphasis on construction plant support in peacetime construction projects. Commercial aggregate plants can, under contract, easily provide all the materials needed for construction and do it faster and more dependably than Army engineer units with crushers. This fact, coupled with



political pressures to funnel construction dollars to the civilian sector has resulted in a lack of emphasis on crusher support which, in turn, has resulted in old equipment which can no longer be supported with repair parts. In addition, all but seven engineer units with assigned rock crushers have been placed in the Reserve and Guard force. Because of the way the Reserve units train, crusher teams are not readily available to support active construction units on short notice. In addition, the equipment in Army units is small and will not meet all the requirements anticipated for future conflicts. Finally, the readiness of the equipment in the engineer units is questionable because it is not utilized except for short training periods and its reliability during training is poor. Even more difficult is the challenge of maintaining these units and providing spare parts. Supporting engineer crushing units deployed outside the United States in countries such as Honduras is extremely challenging. The supply system cannot obtain all the specialized parts in a timely manner.

To focus on the crusher problem, a look at history will help analyze the equipment needs of today. The experiences of Vietnam and current Central American projects which have used commercial equipment (which has not changed much in 20 years) will support the recommendations to upgrade the Army's rock crusher equipment. The force structure which

presently provides crusher support will also be discussed, however, equipment, not structure, appears to be the problem for the future.

A basic assumption is made that the LOC mission will remain with the Corps of Engineers. No other alternative for the production of rock is available to support combat operations. In undeveloped or developing countries, a self-contained U.S. military capability with crusher teams is the only means of support. Another assumption is that the Army will continue to support developing countries. This support is usually very beneficial to establishing or preserving strong diplomatic relations between developing nations and the U.S. and allows for assistance without the involvement of combat forces.

For clarification, two terms must be defined. First, construction plants consist of the equipment required for the production of aggregate used in construction. This equipment normally includes crushers which transform natural rock into usable construction materials. The focus is on the crushing and screening plants which break feed rock, screen the product, and sort it by size into stockpiles. Secondly, the rock crusher is the main part of this special purpose engineer equipment. The size and design of the crushers vary based on the quantity of rock required, its size, hardness, and abrasiveness. Crusher plants can be both fixed for large long term requirements or mobile to

meet changing requirements of many smaller projects. This discussion is limited to the mobile units because the Army has the responsibility to deploy to a multitude of locations with potentially different requirements and situations. The equipment which the Army has now is mobile, but it is antiquated and too small for the growing demands of construction in the theater of operation.

## DISCUSSION

To begin the discussion of construction plant requirements, an explanation is necessary of what they do and why they are needed. The construction of LDCs and facilities requires rock as a base to transfer loads from equipment and/or structures to the ground. Rock is the most plentiful source of base material. When rock is crushed, broken into irregular and non-rounded shapes which interlock, it provides a strong workable material which can distribute heavy loads to the ground. When rock of varying sizes is mixed, large to small, it can be compacted to form a very stable base. Normally rock is compacted with heavy rollers or vibration equipment to achieve the compaction necessary to develop a base thick enough to carry the loads resulting from moving equipment or stored material without causing surface deformation. Another major use of aggregate is the production of concrete and asphalt pavement for construction.

The aggregate needed for construction is produced by the construction plant with crushing and screening equipment. The specific operation may vary due to the nature of the source material and the requirements for the finished product. The process generally includes quarry or gravel pit operations to provide source material, crushing, screening, sizing operations, washing, or a combination of

the above. Portable crushing equipment has been provided to designated engineer units to meet aggregate production requirements. This equipment must be capable of receiving the material from the quarry, performing the necessary reduction and processing, and producing the finished aggregate in sufficient quality and quantity to meet job requirements. Project planning often identifies crushing operations as a critical item in meeting schedules.

#### HISTORICAL BACKGROUND

The capacity of crusher plants varies depending on equipment weight, size, and the output needed. The output from the crushing and screening plant needs to meet all construction requirements. Determining this output is difficult because the damage caused by war is hard to predict. The approach taken here is to review the Corps involvement in past wars and conflicts and see if history has identified the best size for replacement equipment. The focus is on WWII, Vietnam, and current construction projects in Honduras. Sufficient data on construction in Korea was not available.

#### Initial Development

In 1930, the Chief of Engineers, who was charged with the building and maintenance of roads in the combat zone and zone of communications, began a project to study machines for engineer operations in the field. One phase of this

study covered stone crushing and screening equipment which would provide gravel for roads and general construction. Fortunately, commercial road equipment companies had already made progress in developing mobile equipment. The theory was that two types of this commercial mobile equipment would be needed. A light or medium crusher was needed for the combat zone while a heavy unit would provide increased capacity to the communications zone. The Board on Engineer Equipment assumed the mission to develop the crushing and screening capability because of the emphasis upon mobility of the mechanized Army and an increased emphasis on road building and maintenance. The initial study centered on two-stage plants, with a primary crusher for initial reduction and a secondary unit for further reduction. Single unit crushers were also considered because of the potential for reduced weight and shipping space. Testing of the two-stage crusher, with a 25 ton per hour (TPH) capacity for 1 inch material to meet the medium requirement, started in 1941. Specifications were prepared by an expert in the field, CPT V. G. Gould, a past member of the Board and an engineer for the Iowa State Highway Department.<sup>1</sup>

The two-stage plants included a primary jaw crusher with a power supply, a loading hopper, a feeder and a conveyor to move material to the secondary unit. The secondary unit was a roll-crusher with power source, a feeder, a feed conveyor, a reject conveyor, screens, and a

delivery conveyor for final product storage. Before testing was completed, the Japanese attacked Pearl Harbor. Soon thereafter, the Chief of Engineers ordered procurement of 14 units. At the same time, standardization was expedited.<sup>2</sup>

CPT Gould also proposed a Road Battalion for road construction which would be fully equipped, except for crushing equipment which could be attached. His proposal suggested placing one medium crusher plant at each corps depot. Further, each army depot was to receive three large mobile crushers that could produce 75 cubic yards per hour. The Engineer Board did not support his recommendation, but instead formed Park Battalions with crusher equipment to support field projects.<sup>3</sup>

Single unit crushers with variable adjustment jaws were examined in 1942 which lead to further testing and competition with the two-stage plants. Test results showed the two-stage model had 35 to 60% greater capacity, was more accessible for component repair, and was more versatile with two crushers being able to operate independently. The two-stage unit was harder to move and was heavier. The single stage unit was light, required less power, and was easier to set-up. The decision of the Board supported the two-stage model based on no significant difference in weight and space, availability of repair parts, and the fact that procurement of the two-stage plant was already underway. This decision was also supported by the Chief of Engineers.<sup>4</sup>

During 1943-1944, 385 small 25 cubic yard crushers and screening plants were distributed to the Army in the field with over 160 going to Europe, 100 plus to the Pacific and the remainder to Lend-Lease for the British and other allies. The units performed efficiently and met the need satisfactorily.<sup>5</sup>

#### WWII in Europe

WWII showed a significant need for combat construction, especially for roads, railroads, and airfields. These requirements were throughout the theaters. In January 1943, for example, the 38th Engineer General Services Regiment began construction in North Africa of a 6000 foot long by 200 foot wide runway. Equipment was in short supply so local civilians and contractors were used. Ten to fifteen small local crushers and 1000 civilians with hammers produced the rock. Each person could chip about half a ton of stone each day. By hand, the people produced more than all the crushers. Even without adequate equipment, 50,000 yards of stone were provided so that the airfield was ready by June 1943.<sup>6</sup>

In Italy and elsewhere, engineers constructed roads, pipelines, railroads, and other general engineering projects requiring rock. Materiel from 134 Liberty ships supported the engineer operation from October 1943 to April 1945. This equipment supported 27 rock quarries operated by



engineers which produced 801,000 cubic yards of crushed stone for roads and port repairs.<sup>7</sup>

Prior to the invasion of Europe, LTG. J.C.H. Lee, Commanding General, Service Forces, European Theater, made the following remarks on the importance of lines of communications.

"Lacking lines of communications, an Army does not march at all, even though provided with the best food the land affords. Essential lines of communications, the roads, railways, inland waterways, and pipelines radiating from our ports of entry, form the skeleton on which the future of modern warfare is molded. As the lines are strong and direct, so the attack is hard-hitting and effective. If they are weak or poorly planned, so the advance lacks vigor and stamina. By noting how closely these lines follow the advance, and the overall effectiveness of the support they afford, we can measure directly the extent to which the chief engineer of the theater accomplishes his supply mission."<sup>8</sup>

This quote again points out the importance of LOCs and the mission of the engineer. Engineer supplies seen as essential to mission accomplishment included special equipment including the 150 tph rock crushers which weighed 250 tons each. Their arrival was considered key in the reconstruction of ports, railways, roads, and pipelines. This need for engineer equipment required advanced planning because lead times for many items were one year. Requirements for reconstruction after the invasion of Europe were estimated prior to landing; however, the extent of damage made estimates for engineer supplies extremely

difficult. Estimates based on the number of road miles, railways, bridges, and pipelines provided the general requirement. Demolition and the enemy's "Track Rooters", which destroyed roadbeds were difficult to predict. The estimate of engineer supplies was 1.3 million tons. Initial demands for sand and gravel were presumed to be available for procurement until crushers could be set up.<sup>9</sup>

Engineer road maintenance was dependent on crushed rock to offset deterioration due to weather and traffic. Repair of shellfire and bomb damage was normally accomplished by compacting rock into craters. Rock quarry operations were established to keep roads open after the rains of late September of 1944. Rock was further stockpiled for winter movement to keep main supply routes open.<sup>10</sup> Again, the capacity of crusher operations was not specifically noted in most articles. Earlier procurements made the smaller 25 cubic yard crushers the most common.

In December 1944, engineer road maintenance in support of III Corps during its attack against the southern portion of the Germans' Ardennes salient contributed to the ultimate success of the operation. After the Spring thaw of 1945, came heavy rains. Applied rock disappeared, roads were impassable, and some units had to be supplied by parachute. One officer told his engineer, "I know you told me the roads would go to pieces, but, hell, you can't even see the pieces."<sup>11</sup> Rock, rock, and more rock was needed for road

repairs. Where roads were completely gone, repairs required in excess of a ton of rock per linear foot of road. Rock was shipped by rail and truck. A commercial quarry just east of Bastogne was opened along with several small quarries using assigned crushers to meet demands.<sup>12</sup>

#### WWII Pacific

In the Pacific theater, crushing equipment became critical. It was the only source in most cases because most islands had no commercial rock operations and what little capability that had been left by the Japanese was too limited to be efficient. Airfields constructed by the Japanese were not adequate for the larger planes of the U.S. Army Air Corps. In most instances, major rebuilding was required to stabilize the runways. Coral was often used as a base material but the asphalt pavement required crushed rock from local quarries or stream beds.<sup>13</sup>

The construction of airdromes involved in many cases the attachment of Army aviation engineer units to Air Corps commands or joint efforts with naval construction battalions. In any case, the end product was normally the improvement or construction of runways and roads. In the Admiralty Islands, for example, three airdromes were constructed. Nearby streams with boulders and gravel bottoms provided feed material for crushing. Small crushers were never able to produce over 300 tons a day while 5000

tons a day were needed. The shortfall required new procedures for mixing and compacting natural material while crushed material was reserved for the final surface.<sup>14</sup>

On Guam, airfield construction was also a priority. The key to the operation was the arrival and set up of a semi-mobile 150 tph rock crusher plant. This was larger than previous equipment and met the requirement for larger capacity plants. The output of the crusher was only 100-120 tph because of large feed rock. The 150 ton asphalt plant which used the rock in production of asphalt paving material was always ahead of its rated output. Again the crusher was the critical element. Concrete construction further placed a demand on the rock crusher since it also required crushed material.<sup>15</sup>

The American forces were not the only troops concerned about rock crushing. Japanese engineer units used small labor intensive crushers. These small machines of four cubic yard capacity were of the "coffee-grinder" variety and had a small output. Their numerous and well selected sites enabled high production via a large expenditure of manpower. These crude crushers were negligible in output capacity compared to the 150 tph plants operated by Army engineers and Seabees. Maintenance for Japanese equipment was also a problem because sizes varied, assemblies were different, and spare parts were not standardized. In comparison, American troops had standardized equipment. The electric arc welder

offered a great advantage, since repairs could be made much easier and faster.<sup>16</sup> Welding is normal maintenance on jaw faces to keep wear down and efficiency up.

#### Vietnam

The Vietnam War provided a great deal of information on construction and rock crushing operations in comparison to the Korean War. When U.S. Army engineers arrived in Vietnam, the economy was incapable of providing construction materials. Only a few old small French quarries existed. Rock was a scarce resource where terrain was sandy and marshy. Base camps and roads were dependent on adequate rock supplies. From the start of U.S. involvement, a construction plan was required. In 1965, large-scale construction efforts were started to develop airfields and road nets. General William C. Westmoreland provided the priorities. Airfields became critical to jungle warfare and were located at strategic points throughout the country. The second priority was on road construction and maintenance. Roads provided the means to move U.S. forces and bring civilian produce to market. Port construction was the third priority. Due to the tremendous need for construction, commercial contractors, such as Pacific Architects and Engineers and Raymond International /Morrison-Knudson (RMK), supplemented U.S. Army engineers by constructing large airfields, roads, and base camps. Vital

to their success was their ability to mobilize their civilian manpower and equipment. One of the major support functions they performed was the operation of construction plants.<sup>17</sup>

From the start of construction in Cam Ranh Bay, rock became the critical material. It was the only means to stabilize construction in sandy and marshy areas. As one commander explained "Rock was the word over there, I woke up in my sleep saying 'rock, rock, rock.'"<sup>18</sup> RMK and the 864th Engineer Battalion opened the first quarry in April 1965 with their equipment consisting of a 75 tph crushing and screening plant. Small plants such as the 75 tph plant provided most of the material until 1966 when commercial equipment started to arrive. In addition to the equipment shortage, except for a few NCOs, engineer commanders were faced with a shortage of trained crusher plant personnel.<sup>19</sup>

In 1966, few rock quarries were in operation, capacity was well below the requirement, and General Westmoreland took action to expand rock production. In 1968, a special purchase of construction equipment was made with Military Construction Army (MCA) funding resulting in the shipment of eight new mobile 250 tph crushing and screening plants. In the interim, six 225 tph crushing plants were released from depots to replace some of the worn out 75 tph units already in country. Additionally, support equipment for crusher operations was purchased in the form of rock drills,

compressors, large capacity scooploaders, and dump trucks. By mid 1970, as a result of General Westmoreland's efforts, 18 rock crushing plants were operating in Vietnam. Where as in 1969, production had amounted to 70,000 tons every week, that rate had more than doubled by 1970.<sup>20</sup>

In the Delta, rock was particularly critical and the demand for rock brought in by barge was 150,000 tons per month. Aggregate operations went round the clock to meet the demand for filling the 104 barges. Vung Tau produced 80,000 tons, Thu Duc produced 60,000 tons, and Nay Sam and Nay Sop averaged 32,000 tons a month in support of the Delta Rock Program. The equipment at these quarries included a 225 tph plant and a 250 tph plant.<sup>21</sup>

The LOC Restoration Program was the largest engineer project ever undertaken by the U.S. military in a foreign country. It tied major population centers together with 3,038 miles of modern highways. In addition, 900 miles of railways and numerous airfields were upgraded. Besides the 18 crushers of the Army, civilian contractors operated seven major quarries along with smaller plants run by the Navy, Air Force, and ARVN engineers.<sup>22</sup>

In 1966, an acute shortage of rock in III and IV Corps areas existed. The initial solution was to contract for rock deliveries from Korea. After initial deliveries arrived, the problems associated with offloading operations caused an end to this delivery concept. This failure meant

the expansion of in-country quarries. High volume 250 tph plants solved the problem of the 75 tph units. The new 250 tph plants were as portable as the 75's but were easier to operate and maintain. They also produced at least three times as much rock and required fewer operators.<sup>23</sup>

The University Quarry near Saigon, the largest in the country, was a major source of rock and had the largest backlog of work. In February 1966, the first of the crushing plants, a 250 tph unit, began operating on two ten hour shifts to support construction in and around Saigon. In October, RMK set up the largest crusher in Vietnam. This 42 inch jaw crusher was rated at 400 tph and jumped production to 6500 tons per day.<sup>24</sup>

The quarry at Nui Ba Din produced 1000 cubic meters of rock daily in 1967. Two 75 tph crusher plants were used to produce three sizes of rock. Five-inch rock was used for airfield construction and three-inch rock supported road repairs. One-and-a-half-inch rock was used for concrete and asphalt paving. At most quarries, this was a usual mix to meet multiple construction requirements.<sup>25</sup>

Quarries were set up throughout the country to meet the critical rock problem. Qui Nhon, for example, produced more than 8,000 cubic yards of laterite and granite a day using multiple crushers.<sup>26</sup>

The Tam Quan Quarry was another example of a successful operation. In the summer of 1969, this quarry operated with



two 75 tph plants. Maintenance had become a major problem requiring constant support. In December, the two old 75 tph units were replaced by a single 225 tph plant. With the new equipment, the output of crushed rock mushroomed. While the old equipment had produced 189,000 tons of rock in 1969, 112,000 tons were soon produced in less than half a year with the 225 tph plant and engineers expected to triple the previous year's production by the end of 1970.<sup>27</sup>

One of the larger crusher operations was at Vung Tau. The 103rd Engineer Company operated the quarry 24 hours a day in 1967 with two complete 75 tph crusher systems. By 1972, the Vung Tau Quarry was producing 90,000 to 100,000 tons of aggregate monthly and was the largest Army operated quarry. The operation remained a 24 hour effort, but used replacement 250 tph and a 225 tph mobile crushing plants. Efficiency of each plant was not mentioned, however, it was stated that the combined units worked well.<sup>28</sup>

During 1968, road construction was paced by crushed rock production. The Army relied on contractors for 38% of the 180,000 cubic yards of rock monthly to maintain road construction at 285 kilometers per year. Of the 4,103 km requirement, the Army was responsible for 2,520 km. During the MCA buy of equipment, contractors provided "off-the-shelf" equipment with contractor training teams to teach soldiers and assist in initial equipment set-up. Separate contractor support for maintenance and repair parts was

included to sustain the new equipment. This concept of providing new commercial equipment to the Army was successful. Problems still existed, however, in obtaining repair parts for non-standard engineer equipment. Backup maintenance support beyond the user level did not exist. The lack of special tools and the shortage of trained operators and mechanics due to rotations provided constant challenges.<sup>29</sup>

To assist in developing a responsive repair parts program, the Red Ball Express, a high priority special handling system, was formed to support deadlined equipment. For nonstandard engineer equipment which included crushers, maintenance down time was controlled and minimized.<sup>30</sup>

When the U.S. left Vietnam, only 12% of the major construction equipment was returned to the U.S. 50% was worn out equipment and went to property disposal. The remainder of the equipment went to USAID for use in the growth of the Vietnam construction industry.<sup>31</sup>

To conclude the discussion of crushers in Vietnam, some observations from LTG (then Colonel) Ernest Graves, commander of the 34th Engineer Group in Binh Thuy, are provided from an 11 July 1969 interview by CPT Raymond F. Bullock, commander of the 26th Military History detachment. COL. Graves indicated that the MCA procurement of commercial 250 tph jaw-cone crushing plants was an inspiration in supporting the high demand for construction. However, he

felt that commercial equipment had about the same problems as standard military equipment. The operation and maintenance were just as demanding. Skilled operators and repair parts were still a problem. Anticipated wear out of parts had to consider shipping times so that production was not impacted. The big plus was that the equipment was more productive. With commercial equipment, it would have been much better to have had factory representatives to assist with operations and maintenance from the start so that Army engineers and mechanics could have been trained properly. COL Graves concluded with a reminder that the emphasis on rock as a pacing item in construction should not be forgotten.<sup>32</sup>

Command and control of all engineer units and the crushers were important for planning. Two Engineer Brigades, the 18th and 20th each with three engineer groups, provided the planning and supervision for the construction battalions. The 18th Brigade had 11 battalions and the 20th Brigade had ten battalions. Since, each brigade habitually supports a corps, similar engineer capability could exist in any conflict. The crusher support provided in Vietnam with 14 large 225 and 250 tph units reinforces the need for an expanded construction plant capability and shows that assigned battalions could effectively use all the available rock in accomplishing their missions.

## Construction in Honduras

Honduras has provided a major training area for engineers since 1984. Both Active and Reserve engineers have used Honduras as a training area for major projects to include the construction of forward support airfields, roads, and numerous general construction jobs. The major road projects have used construction plants to provide the crushed rock needed for base course and surface material. Crushing equipment used has been primarily limited to 75 tph plants of the Vietnam vintage. Although much engineer equipment has been modernized such as dump trucks, scrapers, graders, and compressors, nothing has been done to upgrade crusher equipment which is 20 to 25 years old.

Crushing operations in Honduras as well as the U.S. have shown a major weakness. The decreasing reliability of equipment in Honduras and the inability to provide repair parts have reduced production and slowed construction efforts. In November 1987, CPT Harvey Allesa, 13th Engineer Company (CS), confirmed the reliability and maintainability problems of existing equipment. His experience on previous deployments showed severe problems in keeping two old 75 tph plants operational. In fact, during his unit's last deployment in 1987, he indicated that one of the two units was down most of the deployment. Problems were experienced mainly with maintenance procedures and non availability of repair parts. CPT Allesa stated that many repair parts were

not available in the supply system and that old salvaged equipment was often used to keep his equipment operational.

Engineer units planning for deployments to Honduras now are raising serious concerns regarding 75 tph units. The main concerns have been the availability of repair parts and the supportability of the diesel power plants.<sup>33</sup>

The problem has not been limited to deploying units. Ft. Leonard Wood, which has a 75 tph unit for training, is also experiencing severe operational problems. Their old crushing equipment is averaging an operationally ready rate of 46% each month. This is particularly significant considering the availability of personnel at Ft. Leonard Wood who teach engineer equipment maintenance courses. One factor which contributes to the problem is that the once reliable repair parts sources are ceasing to exist.<sup>34</sup> The present problem appears to be Army wide and not directed at any one unit. Age is taking a toll on equipment and engineers are finding that the required capability has deteriorated. Without corrective measures, the decline in readiness will continue.

Rock crusher requirements for exercises "FEURTES CAMINOS 88" in Honduras have been identified as critical to the success of the operation. The realization that past problems have existed with the Army's 75 tph plant has necessitated the need to rent equipment. Justification was based on the availability of three 75 tph plants for

deployment and the number of operational days available to complete the job. Optimum performance of existing equipment should produce 1800 tons per day or 600 tons per unit. Experience, however, from past exercises has shown that only 225 tons per day are averaged. This shortfall from the 1100 tons per day requirement forced the decision to lease commercially available equipment. The projected output of the commercial equipment would allow one crushing and screening plant, an Eagle Jumbo 1000 with a 200 tph output, to easily meet requirements. The input feed capacity also allows for the use of larger blast rock averaging 40 inches instead of the standard 30 inch size.<sup>35</sup>

Vietnam and Honduras demonstrate that the Army has relied totally on its truck fleet to haul contractor rock instead of producing its own rock. Given the time, funding, and high priority which we had in Vietnam, contractors can be mobilized to supplement the Army's mission. In Honduras, as in Vietnam, the Army cannot support itself and needs to upgrade its capabilities, however, counting on contractors for rock is a mistake in developing countries where projects are frequently located in isolated areas that are difficult to resupply. The mission remains, but deteriorating equipment without repair parts is simply not capable of meeting the demands for its product. This must be resolved.

## THE EQUIPMENT IN THE CORPS

The Army engineer units which provide crusher support are the construction support companies which are authorized to have 225 tph plants, the engineer quarry 75 tph team, and the engineer quarry 225 tph team. These organizations are designed to provide crushing operations in support of the engineer brigades and groups. All are designed to support major horizontal construction projects such as roads and airfields. The companies are usually assigned to the corps engineer brigades while the teams are attached or assigned to the engineer groups and their battalions or construction support equipment companies for specific projects. In this way, projects can be supported based on requirements and the priorities of the senior engineer. There are presently 29 of the 43 authorized 75 tph crusher and screening plants in 34 companies and teams based on information from CPT. Stanley Thomas, Force Development, Ft. Belvoir. The 13th Engineer Construction Support Company, for example, has three 75 tph units in place of its authorized 225 tph plant. This is a problem because the capacity is not the same and maintenance requirements are higher for the three units than they would be for one large plant. The standard plants are two-stage plants with jaw primary and roll secondary crushers. Their optimum output is 130 tph, but often output dips to 32 tph due maintenance and other operational

factors. Only one Reserve combat support company and the Reserve Training Center at Ft. Pickett have the larger 225 tph plants. Both plants are of the Vietnam vintage making them less reliable and approximately 20 years old.<sup>36</sup>

#### CONSTRUCTION PLANT REQUIREMENTS

Construction plant requirements are not a simple issue. Many factors need to be considered. First, output is determined by the project being constructed. The need for rock in the past 20 years, since the last 75's were procured, has constantly increased to meet the need for heavier loads, higher traffic density, longer runways, and an increased demand for general construction projects in excess of LOC requirements. The demands of WWII depleted all available crushed rock. Vietnam requirements produced a need for contractors and the special procurement of larger crushing plants. Honduras has shown a continuing demand much of which is in excess of one standard 75. The units specially procured in Vietnam seemed to meet most requirements at the engineer group level. As a result of past and present lessons, procurement of crusher screening plants smaller than 225 or 250 tph would not be prudent considering the growing demands for aggregate in engineering projects. The larger capacity would keep up with demand, support surge requirements, allow more opportunity for maintenance, and subject the equipment to less strain and



wear. The second consideration is the ability to handle harder materials without significant loss of output. Higher output for a smaller product, such as two-inches and smaller, would also sustain asphalt pavement and concrete production requirements. Hardness factors greater than six tend to be too brittle for construction and should be avoided in favor of more durable rock.<sup>37</sup> Finally, the consideration of mobility is a factor. The weight of new equipment has constantly decreased from the early plants which weighed 250 tons for a 150 tph unit to only 50 tons for 200 tph output plants. Size has varied but has remained within national standards for highway and rail shipment. This modern equipment, therefore, can easily accompany other large construction equipment in heavy battalions when they are deployed by ship.

The mission of the Corps will not change as long as engineers support the movement of combat forces. LOCs will continue to be high priority users of rock. Thus, there will continue to be a need to maintain a strong capability for construction anywhere engineers are sent, especially where security does not exist for civilian contractors.

Support for this mission has resulted in other agencies working to identify requirements. One such effort has been completed by the Science Applications International Corporation (SAIC). SAIC under contract with the Belvoir Research and Development Center was to determine the

requirements for rock in a division area of operation. The SAIC study used computer modeling to generate requirements for the 24th Infantry Division (MECH). The model includes the Division's portion of support back to the port. Based on computer generated requirements, crusher projections were developed. This approach differs from the historical look in that it concentrates only on one division's area and not on a complete theater of operations. The approved scenario used by the study is the Support Requirements Analysis-FY 93 which satisfies most engineer criteria and has been approved by Headquarters, Department of the Army for analysis of support force requirements. The Engineer Assessment Southwest Asia (EASWA) was also used to simulate damages in the rear areas behind the division.

The SAIC study has taken a comprehensive look at all requirements for roads, airfields, and hardstands. Preliminary results from Mr. Jim Baldridge, SAIC, have shown a significant need for rock. The study indicates a divisional requirement of 480,000 tons in the first 140 days of conflict. The equipment which would normally be assigned would consist of one 225tph and four 75tph plants. Collectively this equipment has an output of only 408,000 tons in 140 days leaving a shortfall of 72,000 tons. The point to be emphasized is that the requirements in the study are minimums. The expansion of single lane roads, multiple road access to port facilities, and support for troop

buildup were not included in the simulation which may be unrealistic when compared to historical needs shown in Vietnam. In any case, the SAIC study supports the need for additional equipment without even considering the need for excess capacity for contingency requirements and weather factors.

In addition to the SAIC study, the Waterways Experiment Station (WES) has completed a study of available commercial state-of-the-art crushing equipment. Within the study is a comparison of cone verses roll crushers as an alternative for replacement equipment. The investigation showed that 145 crushers were purchased between 1962 to 1967. These crushers were 75 tph, jaw primary and roll secondary, plants. Due to their age, and a lack of spare parts, production output of each unit has been greatly reduced.

Changes in crusher design over the past 20 years have been minor. The WES study indicated that jaw crushers remain the favored primary unit for initial rock reduction. Cone crushers are generally preferred for secondary reduction. The eight 250 tph units purchased for Vietnam were of this type. Roll crushers are losing favor in high production equipment because of product quality and higher maintenance costs. The majority of crusher manufacturers produce single crusher plants. They are more compact and can out produce the standard 75s in the Army. The WES study recommendation selected two-stage crushers because of their

greater versatility in field operations. The configuration supported by the study was a jaw-cone crusher combination with a standard vibratory screen deck. This jaw-cone crusher is more versatile in providing a greater variety of uniform fine material for base course work, asphalt paving, and concrete production. This is a change from the jaw-roll plants now in the Army. No additional people would be required and unit organizations would not require significant changes.<sup>38</sup>

Further equipment information was obtained by talking with Mr. Charles R. Spencer from the Morrison-Knudsen Company (MK). Mr. Spencer is an engineer specializing in the design of material handling systems, rock crushing, and screening plants. He is experienced in supporting the Army with crushers both in Vietnam and in projects of the more recent past, such as completion of the Point Salinas Airfield in Grenada. In the design of construction plants, many engineering considerations were discussed which have become standard design factors. In general, MK usually designs larger systems that are fixed rather than mobile. The design considerations, however, do not change and are therefore applicable to the discussion of portable Army plants. The basic consideration in all plants is that they are subject to overloading and abuse from schedule changes requiring outputs above design capacity. The sometimes hostile and isolated operating environments with minimum

availability of services and spare parts add to the difficulty of operating construction plants. A construction plant, therefore, must be designed and selected so that it is oversized to permit surges and overloads. It must also be sturdy enough to meet severe operating conditions.<sup>39</sup>

Construction plant design is based on the art of engineering and experience gained over time. This art is used in the selection of screening, crushing, conveying, and classifying of the product. The base for design is the specification which outlines the gradation, soundness, limits of foreign materials, and physical properties. Output is then dependent on the maximum aggregate size which decreases as the size of product is reduced. This means the larger the desired output size the greater the output capacity of the given machine.<sup>40</sup>

Crushers normally reduce rock through compression, impact, attrition, and shear. Generally, compression and impact operations control the design. Each type of crusher has its own limitations. The type of material, material characteristics (abrasiveness, grain size, hardness), production requirements, product size and shape, size of feed material, and other economic factors of weight, initial cost, and power consumption dictate the configuration of the construction plants. Granites, siliceous gravel, and other abrasive rock with high silica content, which includes some limestones, are generally more economically crushed in

compression-type crushers. Stage crushing is normally used when harder, more abrasive rock is crushed. The number of stages varies with the product.<sup>41</sup>

The primary crusher handles the feed material from the pit or quarry. The capacity should be at least 25-50% greater than the input material to avoid blocking and bridging stoppages of the primary. Primary crushers are of three types: (1) gyratory; (2) jaw; (3) impact. Gyratory units provide high tonnage capabilities, accept large feed sizes and are generally permanent long term units. Jaw crushers have a lower tonnage capability, but are well suited for harder types of rock, can handle softer material, are adjustable to size, can accept small amounts of soil, loam or clay, and are more resistant to abrasive rock. Impact crushers are high output units which accept larger feed material but are best suited for softer rock such as limestones.<sup>42</sup>

The secondary crusher further reduces feed material. Secondary crushers are: (1) standard cone; (2) gyratory; (3) impact; (4) roll. The standard cone machines support high volume operations, can crush hard and soft rock, and have an easily adjusted discharge setting. Gyratory units are similar to the cone type except they are better suited to larger operations. Impact units are again best for softer material but produce a well-shaped product. Roll crushers have low reduction ratios, need smaller feed material, work

best with softer rock, have a high roll wear in abrasive rock, and often produce a flat or a wedge shaped product which is good for asphalt paving but not for concrete.<sup>43</sup>

The general rule of thumb for crushers is to use jaw crushers as primary units unless operations are permanent. Secondary crushers should be of the standard cone type unless specifications dictate special considerations.<sup>44</sup>

Adequate forecasting of consumable supplies and repair parts requirements has been a problem for the Army in the past. Most major manufactures have tables and charts available to the Army which predict wearout for given hours of operation in various types of rock. The availability of these charts can assist units in the determination of supplies needed for stockage and the prediction of reorder points. For estimates involving a large amount of crushing, samples can be sent to testing facilities, such as Allis-Chalmers, for determination of the work index, abrasive index, and test crushing so that liner wear can be predicted more accurately. Manufacturers' replacement statistics are normally available for all other reparable parts. The crushing process has not changed much, however, crusher efficiency has improved along with improved equipment reliability.<sup>45</sup>

## CONSTRUCTION TRAINING

As mentioned, the training philosophy for construction units since Vietnam has been to buy rock from commercial contractors and haul it in unit dump trucks. This allows units to train in an artificial environment which eliminates the problems which history has shown with crusher support. Commercially obtained rock satisfies construction training, but ignores the problems of rock production until a unit deploys and requires an attached crusher team. The available training opportunities are also limited by time and funding. Reserve units have much of the equipment, but they only train 39 days a year and that only allows one 12 day period per year to support a construction project. Scheduling is also a problem because it is done at least one year in advance. Since units need to train the way they will deploy, construction plant operations should be part of the training received by combat heavy units. With such a limited time to train annually, proficiency of the soldiers is restricted. The equipment is often not operational if a part is not available; this wastes valuable time during the annual ~~extende~~ training period.

Training equipment at the Engineer School also requires rehabilitation. When operators can not get hands-on experience with equipment, their proficiency decreases. The low readiness rate of the training equipment must be improved so operators will have the chance to develop some



skills before arriving in units. Refresher training is further restricted by unreliable equipment and this impacts the ability to qualify soldiers prior to scheduled training or deployments.

Deployment training to Honduras and other Latin American countries currently offers the best opportunity for engineers to train with all their equipment. The problems experienced with crusher operations have lengthened project schedules, wasted soldiers' time, and increased costs. The opportunity to train out of the United States allows units to perfect their deployment skills, operational procedures, and operator proficiency. Equipment operations and unit TOEs can also be tested individually or with attached teams to verify the proper mix and size of equipment used in a given project. Experience is the best teacher. By increasing the output of rock crushing plants with modern equipment, units might become aware of new problems that arise which could become the limiting factor in combat construction.

Nation building has been a consideration in the type of engineer projects completed in Honduras and other countries. The finished projects benefit both the engineers with training experience and the host country by improving internal road systems and facilities. Developing countries can make efficient use of engineer assistance. This assistance can improve the economic development of the

country by providing better access to markets. The economic benefit provided to developing countries can assist in the development of a sound political, economic, and psychological base for the people. Further, U.S. assistance in construction support may be a significant factor in a developing country's ability to govern itself. The development of self-sufficient construction capabilities is basic to the Army's ability to assist in this mission.

Host nation support in developed countries such as Germany can supply many military needs. Rock is one of these materials. According to Mr. Bruce Springfield from the Engineer Study Center at Fort Belvoir, host nation support in Germany will be able to provide aggregate for at least six months if war begins in Europe. The need, therefore, is not initially a high priority as we build up forces. However, battle damage and support facilities would generate the need. Thus, the capability to respond must exist. Where local commercial firms can assist, they should be used so crushers can be diverted to other projects. In many developing countries, the capacity to produce rock does not exist. For this reason, deploying engineers need to have the construction plants attached.

#### AVAILABLE COURSES OF ACTION

Modifying the force structure by adding more units is not needed. Instead, existing equipment needs to be

upgraded to newer equipment with expanded output. Personnel increases would not be required. The new larger 250 tph mobile crushers available from companies such as Eagle Crusher Company do not require more people because of their improved efficiency. Representatives from Eagle Crusher Company and Tellsmith Corporation along with Mr. Johnson at WES all indicated that no additional operators would be required to those needed for the standard 75s. In fact, manpower savings may result based on the method of operation and the type of equipment procured as a replacement.

Equipment, as mentioned, is commercially available from at least six manufacturers based on the WES survey of industry. The cost of the machinery will vary based on the type and capacity. As an example, the equipment rented for the FEURTES CAMINOS 88 exercise would cost about \$377,000 to purchase. This was a single stage plant with an output of 150 to 200 tph in limestone. The rental cost of the equipment for eight months was estimated at \$172,000, or \$21,500 per month. At this rate, the equipment could pay for itself in 2.2 years.<sup>46</sup> The example just illustrated shows cost savings although the ideal general purpose equipment would be a two-stage plant because of its versatility and adaptability to more types of material. Two stage units would be somewhat more expensive, but the potential savings of owning the equipment over a ten to fifteen year lifetime make them cost effective to purchase.

Maintenance of crusher equipment is usually accomplished by the company or team mechanics. The only higher level support maintenance capability exists in the combat heavy battalions. In most cases, crusher teams would be attached to these larger units for support. Without the training opportunities for maintenance support, operational experience can not be achieved. This again supports the need for a unit to train the way it would deploy before it deploys. Learning under deployed conditions is not the efficient way to learn that a problem exists and what is required to fix the operation. Finally, as maintenance capabilities are being reduced through warrant officer reductions at the heavy battalion level, experience from training is the only way to develop the capability for actual missions.

#### HOW TO OBTAIN EQUIPMENT

The first option to improve construction plant operations is to repair existing equipment. This does not appear to be practical because the standard plants are small and the manufacturer has stated that some components are no longer available because of the equipment age.<sup>47</sup>

A second option would be to lease equipment for all projects. If crusher plant technology was rapidly changing which it is not, serious consideration would be given to leasing. As shown on the previous page, lease costs are

high over a long period of time. Leased equipment might vary by manufacturer for each project resulting in operators being trained only on what they have operated and not on standard equipment. To insure that engineers retain reliable capabilities and a trained force, identical replacement equipment for units is the best way to maintain readiness. Rental equipment takes time to contract for, may not be available when required, and most importantly might not be standardized.

The last and best option is to procure new equipment outright and replace the existing old plants in the engineer units. The method of procurement most appropriate for this commercial equipment would be the nondevelopmental items (NDI) system. American industry has been in the business and has designed mobile systems used by contractors all over the country. Since the Army requirement for rock is similar to that of commercial contractors, there is no justification for separate military design and development. The NDI procedures represent a tailored acquisition process to obtain off-the-shelf items at a reduced cost to the Army with a corresponding savings in the acquisition time for delivery to the units.

The programming and budgeting process could begin with the verification of the present need. To limit the budgetary impact of this requirement, funds could be spread over several years to keep the annual cost impact lower

within the Army. This would also allow time to prepare units and train operators on the new equipment. Multi-year programming should allow for a quick initial capability followed by a gradual build-up to meet the readiness requirements of the force.

#### RECOMMENDATION FOR REPLACEMENT

Based on the age of the current equipment, a shrinking repair parts base, and the nonavailability of selected components, crushing plant replacement is totally justified.

The need for new equipment is also supported by the requirement to expand the output capacity of the crushers. Historical experience, the SAIC Study, and the opportunities for nation building in developing countries demonstrate the need to have larger, more versatile construction plants. New crushing and screening equipment should have excess capabilities to allow for maintenance, normal operating rates, and surge loading as previously mentioned. A commercial 250 tph mobile plant producing a two-inch product using a two stage operation with a jaw primary and cone secondary crusher would provide the best option for the Army to meet a general mission any place in the world. The versatility of the two stage unit allows for dual independent operations, a high rate of output, and the ability to handle all rock suitable for construction projects. Further, improved plant efficiency and

reliability would not require increases in personnel or significant changes to unit organizations.

The recommended 250 tph replacement equipment should be procured immediately to enhance training and deployment capabilities. Priority for this equipment should go first to the training base and the Active brigades and groups followed by the Reserve and National Guard brigades. This would provide the needed responsive support to meet the demands for larger projects in corps and theater army areas. Providing new equipment to the Active engineer groups with continual training and deployment requirements, would insure a trained and deployable force. Upgrading the equipment at the Engineer School, FT. Leonard Wood, would provide trained operators and mechanics.

The procurement should be spread over three years with the first increment of three plants to support the school and two active FORSCOM groups by upgrading team and company equipment. The second increment should replace equipment supporting the third Active group and three corps engineer brigades. The third phase would consist of the final four plants to reinforce the remainder of the brigades. The remaining 75 ton units in the force should be inspected for replacement or, if practical, a complete rebuild. The reconditioning should be based on a potential for rebuild and the utilization of salvaged plants as an initial source of repair parts controlled by one central activity. The

inspection of equipment should be done jointly by representatives from both the Army and the manufacturer. Based upon the inspection of equipment, further procurement action may be justified to finalize the upgrade of all Army construction plants.

The procurement process should follow the NDI procedures. Testing should be limited to a competitive comparison of equipment output based on size and particle characteristics, and a range of material hardness. Maintainability of the equipment and accessibility to components and adjustments should be considered major factors in the selection process. Programming actions to support procurement should begin with the next Program Objective Memorandum (POM) formulation. Once the manufacturer is selected, similar equipment should be procured for each annual buy to insure standardization and supportability. The slow changes in this technology also allow for acquiring identical standardized equipment over a period of several years.

During the programming and budgeting process, lease considerations should be supported to develop experience with larger crushers. This experience should be incorporated into the competitive testing process so that problems encountered are minimized before the final decision is made to procure one type of equipment.



## CONCLUSION

The Corps of Engineers has a serious problem with the reliability and maintainability of its existing 20 year old construction plants. Neither history nor computer simulations justify adhering to the size of current equipment for projected aggregate requirements. The realization that lines of communications are going to remain a critical priority in supporting the maneuver force suggests that action must be taken now to begin to correct this problem.

Replacement construction plants should incorporate 250 tph equipment which provides additional and flexible output. Expanded output would insure that the crusher plants will no longer be the limiting factor in project scheduling and completion times. Added output would further allow equipment to operate at a more efficient rate so that it is not constantly operating under a maximum output condition. Average loading requirements would increase equipment life and reduce component deterioration rates. Maintenance requirements would also be reduced and become more predictable. Normal loading would increase the unit commander's ability to project parts for replacement.

Immediate procurement in increments would reduce the initial budget impact and provide some early capability.

Follow-on procurement of identical equipment would provide a strong base to support military construction, nation building in developing countries, and LOC rebuilding in theaters of operation. The initial buy of equipment would allow time to evaluate the feasibility of up-grading the remaining 75 tph plants and to provide for a limited parts base. Purchase of the initial 11 plants would improve the capabilities of all the engineer brigades and groups to support the combat corps. Training programs at the Engineer School would be enhanced by using new state-of-the-art equipment.

If these limitations in equipment are not recognized, engineer units will not be capable of accomplishing construction projects except where commercial companies or host nation support can provide the requirement for construction aggregate. The present engineer construction force has enormous capabilities to accomplish its construction mission but the material required for this construction must be available. Without engineer construction support, the combat forces will be hampered by the limited movement of supplies and the decreased ability to maneuver using the roads, railways, airfields, and ports of the theater.

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